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Student Notes
Science on Saturday
Lawrence Livermore National Laboratory
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Comets and the Stardust Mission:
What's in our Solar System's Freezer?

Presenters:

Dr. Hope Ishii
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Goal:
Students will learn about the nature of comets and how scientists at LLNL are studying comet samples returned to Earth by the Stardust mission, and how these tiny samples of space dust may hold the key to understanding the formation of our own Solar System.

Questions:
You will be able to answer the following questions at the end of this presentation:

- Why have comets historically been feared?
- What are comets made of?
- What is the nature of comet tails?
- Where are comets found in the Solar System?
- How can you make a "comet" in a classroom?
- Why do we study comets?
- How did the Stardust probe collect samples from the comet Wild-2, and return those samples to the Earth?
- What surprising insights about our Solar System have we learned by studying the Wild-2 comet samples?

Listen carefully to the presentation to answer the questions during the talk. You will need these answers to get credit from your teacher.

1. What are the "normal" objects one might expect to see in the sky on a clear night?

2. How are comets different from these "normal" objects?

3. List in order, from largest object to smallest: A comet nucleus, Earth, Pluto, Earth's Moon, Charon (Pluto's moon).

4. Which of the following is NOT part of a comet's composition? (More than one may be correct.)
    a. Water ice
    b. Frozen carbon dioxide
    c. Minerals (rocks and dust)
    d. An iron/nickel core
    e. Organic (carbon-based) compounds
    f. Nougat and caramel

5. What are the two tails of a comet made of?

6. In which direction does a comet's tails point?
    a. The direction the comet is going.
    b. The direction the comet is coming from.
    c. Away from the Sun.
    d. Toward the Sun.
    e. Toward Albuquerque, New Mexico

7. True or False: The planets of our Solar System, and everything on them – including us – were formed from stardust ejected from other stars in our Galaxy.

8. How long ago did our Solar System form?

9. In the early Solar Nebula, what did bodies closer to our Sun than the "frost line" tend to be made of? What about objects farther than the "frost line?"

10. True or False: Comets act like frozen time capsules, containing material preserved since the Solar System formed.

11. True or False: There is no possible connection between the beginning of life on Earth and comet bombardment.

12. How far did the Stardust spacecraft travel from the Earth?
    a. A thousand miles.
    b. A million miles.
    c. 1 A.U.
    d. 2.72 A.U.
    e. 2.72 light years.

13. When was comet Wild-2 deflected from a larger orbit into one that takes it into the inner part of the Solar System?
    a. 4.6 billion years ago.
    b. 65 million years ago.
    c. 60,000 years ago.
    d. 3,000 years ago.
    e. 1974.

14. What type of ultra-low-density material was used by Stardust to capture comet dust?

15. Which is wider: a human hair or a typical comet sample returned by Stardust?

16. True or false: LLNL scientists have found rocky material in the Stardust samples that seems to have been heated by the Sun at some point, implying the material used to be close to the Sun, and then was churned into the outer part of the Solar System long ago.

Some Websites of Interest:

- http://education.llnl.gov/ *(LLNL Science and Technology Education Program (STEP))*
- http://stardust.jpl.nasa.gov/home/index.html *(Jet Propulsion Laboratory's Stardust Homepage)*
- http://www.llnl.gov/pao/news/news_releases/2006/NR-06-12-03.html *(LLNL Press Release – Comet Particles Tell a New Story about the Birth of the Solar System.)*
- http://stardustathome.ssl.berkeley.edu/ *(Stardust@Home)*
- http://www.noao.edu/education/crecipe.html *(Recipe & instructions for making a comet)*
- http://csep10.phys.utk.edu/astr161/lect/comets/comets.html *(an online astronomy course from the University of Tennessee, Knoxville)*
- http://www.windows.ucar.edu/tour/link=/comets/comet_model_interactive.html *(A very cool interactive site where you can play with various comets' orbital parameters and observe the effects.)*
- http://cse.ssl.berkeley.edu/SegwayEd/lessons/cometstale/com.html *(an educational website from the Space Science Laboratory at UC Berkeley)*
- http://www.ifa.hawaii.edu/~jewitt/comet.html *(for those who are really interested in more details, a website by one of the world's experts on comets)*

Science Content Standards covered in this presentation:
Grades Nine Through Twelve, Earth Sciences, Earth's Place in the Universe

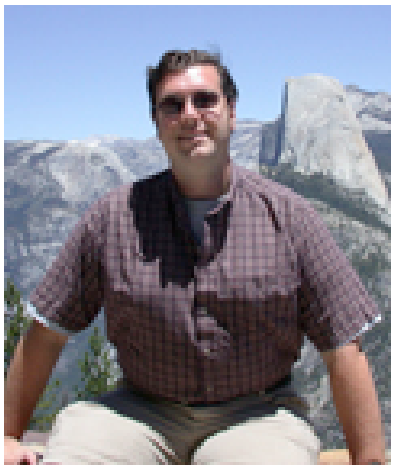
1. Astronomy and planetary exploration reveal the solar system's structure, scale, and change over time. As a basis for understanding this concept:

   a. *Students know* how the differences and similarities among the sun, the terrestrial planets, and the gas planets may have been established during the formation of the solar system.
   b. *Students know* the evidence from Earth and moon rocks indicates that the solar system was formed from a nebular cloud of dust and gas approximately 4.6 billion years ago.
   c. *Students know* the evidence from geological studies of Earth and other planets suggest that the early Earth was very different from Earth today.
   f. Students know the evidence for the dramatic effects that asteroid impacts have had in shaping the surface of planets and their moons and in mass extinctions of life on Earth.

Dr. Hope Ishii

Research Scientist, Institute for Geophysics and Planetary Physics Lawrence Livermore National Laboratory

Hope earned her Bachelor's degree in Materials Science and Engineering from Cornell University and her Ph.D. at Stanford University. In between, she traveled to Sweden for her Master's degree in Physics and Engineering Physics. She has studied a wide range of materials from nanocomposites to liquid crystals to glass and specializes in synchrotron x-ray studies. Since 2003, Hope has been at Lawrence Livermore National Laboratory studying extraterrestrial samples and the stories these materials tell about our solar system. Most recently, she has been studying comet dust from NASA's Stardust mission.



Tom Shefler

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Dan Burns has been teaching Earth and Space Science and AP Physics at Los Gatos High School for 12 years. He is the LGHS science department chair and past president of the Northern California/Nevada American Association of Physics Teachers. He has worked on curriculum development and teacher workshops for the SETI Institute, the USGS, NASA, AAPT, and San Jose State University. He has a BS in Aerospace Engineering from the University of Illinois. Prior to becoming a teacher Dan was a senior research specialist for the Lockheed Missiles and Space Company. Dan is an avid amateur astronomer and astrophotographer and has had several pictures published in astronomy magazines.